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Application of free selection in mixed forests of the inland northwestern United States

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Abstract

Forest management objectives continue to evolve as the desires and needs of society change. The practice of silviculture has risen to the challenge by supplying silvicultural methods and systems to produce desired stand and forest structures and compositions to meet these changing objectives. For the most part, the practice of silviculture offers a robust set of procedures well suited for the timely and efficient production of timber crops, but often leaving simplified forests that do not necessarily reflect historical conditions, do neither provide a full range of wildlife habitats, nor provide a sense of place for many different forest users. We propose a silvicultural system that we call ‘‘free selection’’. This multi-entry, uneven-aged system is intended for use in forests in which the remaining structure and composition is paramount. It is well suited for restoring the old-growth character of forests as well as reducing the risk of wildfire within the urban interface. Rather than using precise stand structural guidelines to define the stand treatments, we suggest that a well articulated ‘‘vision’’ of the immediate and desired future conditions is used to guide the planning and control the marking. This vision accounts for the interaction of all components of a forest from below ground to the high forest canopy. It relies on an integrated ecological view of how forests function. We have applied free selection guided by such a vision in both the moist (*Thuja plicata* Donn. ex D. Don, *Abies grandis* (Dougl. ex D. Don) Lindl., *Tsuga heterophylla* [Raf.] Sarg.) forests of northern Idaho to reduce the risk of wildfire damaging historical buildings and in the dry (*Pinus ponderosa* Dougl. ex Laws.) forests of southern Idaho to restore their old-growth character.

Keywords: Silvicultural systems; Restoration; Urban interface; Uneven-aged systems

1. Introduction

Silviculture is the art and science of influencing the establishment, growth, composition, health and quality of forests to meet the diverse needs and values (management objectives) of landowners and society on a sustainable basis (Helms, 1998). Through time, silviculture has evolved as a consequence of the progression in values and needs of landowners and society. Silviculture is a highly integrative discipline (see Figure 1-1 in Nyland (2002)) and, as an applied science, it is a continuing, informal kind of research in which understanding is sought and new ideas are applied (Smith et al., 1997).

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Although timber and fiber production are still among the management objectives in many forests, other values such as water quantity and quality, biodiversity, scenery, old-growth, wildfire resilient and resistant forests, and protecting and preserving the spiritual or sense of place[1] in forests are emerging issues. Sense of place is a holistic concept that focuses on the subjective and often shared experience or attachment to the landscape emotionally or symbolically. It involves a subjective experience or view of place description of the meanings, images, and attachments people give to specific locations. These places reflect the perception people have of a physical area where they interact, whether for a few minutes or a lifetime, giving that area special meaning to them, their community, or culture (Galliano and Loeffler, 1999). Many of these values depend upon the development and maintenance of complex and interacting forest elements such as high forest cover (presence of tall and/or large trees), disturbance, vegetation patchiness, multiple canopies (vertical diversity), old trees and decadence, down logs, and the presence and interspersion of a complete suite of vegetative structural stages inherent to a forest (see Thomas (1979), Reynolds et al. (1992), Galliano and Loeffler (1999) and Franklin et al. (2002)). Even though traditional silvicultural systems have ultimate flexibility, these emerging values and the complex combination of forest elements cannot be readily quantified, modeled, or translated into traditional stand metrics (Franklin et al., 2002; Backlund and Williams, 2004). In addition, many of the current (2004) forests of the western United States no longer reflect the composition and structure of historical forests (1800s). Fire exclusion, animal grazing, timber harvesting, exotic species introductions, and climate shifts all contributed to creating the current forests which, in general, have higher densities, and different tree species that were not apparent in past forests (Covington and Moore, 1994; Quigley et al., 1996; Graham, 2003). Because of these changes, current forests appear at a greater risk to epidemic insect and disease infestations and the occurrence of large crown fires than many historical forests (Graham et al., 2004).

This all poses a unique challenge to silviculturists. Yet, because silviculture is founded on studies of the life history of forests and has been honed by experience from more than 100 years of management, it is well suited for meeting these challenges. In particular, the concepts and methods inherent in traditional even-aged and uneven-aged systems can be used for developing and maintaining forests that meet these new and emerging objectives. This is a perspective that the forestry community needs to better recognize and contemplate and foresters must become emboldened about using and implementing them in innovative and creative ways in order to meet the challenges of the 21st Century (see O'Hara et al. (1994)).

2. Selection systems

Both group and single-selection systems maintain high forest cover which is an important component to many current management objectives (Marquis, 1978; Smith et al., 1997; Nyland, 2002). One widely accepted procedure for determining uneven-aged (diameter) distributions is to use a fixed quotient (q) between numbers of trees in successive diameter classes. That is, starting with the number of trees in the largest diameter class in a stand, each subsequent smaller diameter class would contain q times as many trees in the next higher diameter class (Meyer et al., 1961; Marquis, 1978). Often q-defined structures are not ecologically meaningful. They are arbitrarily selected and appreciated for the mathematical convenience of generating a target diameter distribution (O'Hara, 1996). They are most relied upon when other distributions are not identified or articulated. Although this technique provides precise views of desired structures and discloses targets that can be readily translated to silviculture prescriptions such defined stand structures tend to have less diversity than those occurring naturally (Nyland, 2002).

During our research, we have applied selection systems based on diameter distributions (qs), residual

[1] The importance of this concept was exemplified after the tragic events of September 11 when the USDA Forest Service and the USDI Park Service waived entrance fees during Veteran's Day weekend to "help Americans find comfort and solace". Forest Service Chief Dale Bosworth stated "National forests and grasslands can offer peaceful experiences and spiritual renewal". This gesture on the part of public land management agencies acknowledges the importance of the experiences people have in natural places (Schroeder, 2002).

basal area, and target tree size (BDq) (Graham and Smith, 1983; Graham et al., 1999). In doing so, we found them difficult to implement and that intensive stand inventories are needed and often multiple passes through a stand are required to approach the often artificial diameter distributions defined by a "q" (see Marquis (1978)). In our experience, mortality is often continuous and exacerbated by the cuttings (Graham, 1980); damage from ice, snow, or wind often compromises stand structure goals making the target BDq distributions irrelevant. Also, regeneration of shade-tolerant species has often distorted the lower end of target structures, even though cleanings were used to manage this cohort (Graham et al., 1999).

The application of group selection has the same intrinsic difficulties as the single-tree selection system but additional issues arise. These include locating, marking, regenerating, keeping track of the groups, and planning future entries (groups to regenerate and those to tend) to maintain the desired conditions in a stand and across a landscape. Most importantly, even with including complex reserve tree, group, and patch metrics (e.g., species preference lists, irregular spacing, snag guidelines, down log guidelines), such defined structures most often will not emulate horizontal tree distributions or the juxtaposition of the different structural stages inherent to natural forests (Thomas, 1979; Reynolds et al., 1992; Franklin et al., 2002).

2.1. Free selection

Elements from both even-aged and uneven-aged silviculture can be integrated to produce diverse stand compositions and structures (Nyland, 2002). Such a system might include provisions for maintaining a variety of structural stages, tree densities, patch sizes, compositions, tree sizes, etc. within stands and across landscapes in a pattern reminiscent of those that historically occurred (Long and Smith, 2000). The system provides for snags, decadence, down wood, and often overlooked forest components (e.g., interlocking crowns, interspersion of structural stages, disturbance) that are relevant to many current forests and management objectives. We call such a hybrid system "free selection". It is a silvicultural system suited for maintaining forests with high cover and heterogeneity both in composition and structure. Because it is a selection system, it utilizes multiple tending and regenerating entries at various intervals to develop and maintain the desired forest conditions.

Similar to traditional uneven-aged systems, the full range of silvicultural methods from regeneration to thinning can occur at each entry if needed (Smith et al., 1997). Successful regeneration (natural or artificial) is required when implementing the system to ensure that future desired forest conditions are developed and maintained. All tree, shrub, forest floor, and other components need to be evaluated and managed as necessary to create, develop, and maintain the desired forest compositions and structures. Free selection may also incorporate patch cutting to create openings of sufficient size to regenerate early and mid-seral species (e.g., *Pinus monticola* Dougl. Ex D. Donn, *Larix occidentalis* Nutt.), but not necessarily provide them optimum space for long-term development. Subsequent treatments are necessary to tend these regenerated cohorts, releasing selected trees to insure adequate light for good crown development and adequate tree growth (Jain et al., 2004).

Because free selection incorporates multiple entries, patience can be exercised in developing the desired forest structures and compositions. The term "free" indicates that the frequency, kind, and intensity of entries are undetermined but will depend on how the stand develops within the context of the biological and physical environment when fulfilling the desired conditions. However, thresholds or triggers could be described that would indicate the timing, kind, and intensity of treatment required to insure the stand(s) develops as desired. The system could be viewed as stand or landscape level adaptive management (see Franklin et al. (2002)). Even though the practice of silviculture strives to create desirable residual stand conditions, free selection appears to be very appropriate in situations when the condition of the forest after treatment is of paramount importance. This occurs frequently when maintaining conditions for wildlife or providing a feeling of security and wildness in the urban interface (see footnote 1). We suggest free selection is applicable in both the moist and dry forests in the western United States for addressing hazardous wildfire conditions within the wildland–urban interface, restoring and maintaining old forest structures, or for other objectives that require the maintenance of high forest cover and a diversity of forest structures and compositions at various spatial scales.

The concept behind free selection as we describe it is not unique, and others have described similar silvicultural systems. Anderson (1990) proposed a method he called ‘‘tolerant’’ forest management, which has been used in Central and South America. This approach included favoring highly desirable tree species while removing less desirable competitors to maintain essential forest structure and composition. The Palcazù system used in the forests of Peru incorporates the principles of gap dynamics to manage moist tropical forests for both wood and diversity (Hartshorn, 1990). Lorimer (1989) described a combination of group and single-tree selection systems mimicking single and multi-tree gaps for managing deciduous hardwood forests of the north central United States. These examples illustrate novel approaches to using selection systems, however, the main thrust of each one was to produce timber products while mitigating other forest values. In contrast to traditional single-tree and group selection systems that depend on precise diameter (age) distributions, we believe that free selection is best applied using a more flexible approach guided by a vision that describes a desirable set of forest and stand conditions and using silviculture to influence the patterns of development that should occur over time and space.

3. Vision

A vision articulates a comprehensive description of the desired forest conditions both in the short-term (tens of years) and long-term (hundreds of years) over multiple spatial scales ranging from canopy gaps to landscapes. The use of a vision encourages collaboration between and among natural resource disciplines and facilitates a common understanding among the disciplines as to the forest conditions that can fulfill the management objectives. Moreover, a vision can be an excellent communication tool within disciplines and with the public at large.

Based on our experience we believe a vision, based on silvics and ecology is preferred to highly technical stand descriptors that may have limited practical use. No matter how complex and precise a quantitative silvicultural prescription is, it can neither encompass all the structures, compositions, processes, and functions inherent in forests, nor can it include all of the forest conditions that are presented when a prescription is applied[2]. We believe a vision can incorporate a diversity of structures, spatial pattern richness, long time periods, and the complex contribution of disturbances that Franklin et al. (2002) indicate are lacking in traditional silviculture. We found the use of some stand descriptors and especially their variation (e.g., range of tree density in basal area, or range of tree numbers per unit area, variable tree spacing) are often beneficial when communicating a vision. Depending on the management objectives, biophysical setting, along with the social and economic circumstances, a vision could readily be used in developing target stands for lands administered by the U. S. Department of Agriculture Forest Service.

3.1. Vision elements

A vision incorporates both the immediate and future desired forest structure and composition that the biophysical environment will support and we suggest four elements for inclusion in a vision.

3.1.1. Management objectives

Well-defined management objectives are central to developing a vision for any silvicultural prescription. They should be explicit and insure an appropriate outcome at appropriate temporal and spatial scales. The objectives set standards for determining if the treatments succeeded through time.

3.1.2. Theme

A theme describes the relevant structural features of a forest that fulfill the management objectives. A theme should be a holistic view of forests incorporating complex structures (e.g., soils, vegetation, biological legacies), processes (e.g., succession, disturbance), appropriate concepts (e.g., wildlife habitat connectivity, vegetative structural stages), and the recognition of ecological variation relevant to a particular setting

[2] Franklin et al. (2002) suggest that foresters can and must learn to manage stands that sustain biological diversity and a range of essential processes. They describe over 40 complex structures, structural processes, and spatial patterns of structural elements that operate during stand development and they list nine developmental stages of forests.

(Franklin et al., 2002). A comprehensive and inclusive description of the stands and forest is suggested as more important than precise quantification. For example, a theme for a watershed protection objective might read: create and maintain stand and forest conditions that protect the forest floor from soil erosion in the face of both low and high severity wildfires while also desynchronizing peak stream flows among northerly and southerly aspects. A theme for maintaining northern goshawk (forest dwelling hawk, *Accipiter gentiles atricapillus*) habitat might read: create and maintain a mosaic of forest and stand conditions composed of structural stages ranging from regeneration through old-growth and arrange these stages in small patches and clumps of vegetation across landscapes. A theme that we have used quite successfully for the objective of restoring and maintaining an old-growth character in dry forests, as well as for maintaining fire resilient and resistant stands within the urban interface is: develop and maintain a functioning forest that contains all its parts (e.g., plants, animals, biological legacies, vegetation successional stages, and their juxtaposition) and environment (e.g., canopy gaps, forest floor conditions) that would result from endemic levels of native disturbances (insects, diseases, and fire).

3.1.3. Desired stand conditions

The theme can be applied to articulate the desired composition, seral stages, horizontal and vertical structure (mix of structural stages), patchiness, decadence, forest floor conditions, down logs both in the short term and into the future, and other features as required. Also, the tree species preferences for a given situation can be described, as can the regeneration requirements of the various species (tree, forb, and shrub) that may occur on a site. Detailed information about each attribute is not necessary; rather an integrative view of the attributes is suggested when describing the vision. Reference conditions (e.g., historical, hypothetical, functional, etc.) can further explain the vision, with the understanding that these conditions may not be possible, or necessarily desired. However, reference conditions can be used to provide context or give practitioners with a view, feeling, or concept of what the vision is attempting to express (see Franklin et al. (2002)). We have found that a multiple spatial scale approach can be used to provide understanding and to help explain the essence of a vision (Jain et al., 2002).

3.1.4. Current stand conditions

A comprehensive understanding of the current stand conditions (e.g., soils, down wood, ground level vegetation, overstory, wildlife use) and the ongoing disturbances, or lack thereof, help to frame the vision and are essential for planning silvicultural activities.

4. Free selection application

Beginning in the 1990s we used free selection to successfully treat stands in both the moist forests (i.e. those growing on *Thuja plicata* Donn. ex D. Don and *Tsuga heterophylla* [Raf.] Sarg. potential vegetation types) of northern Idaho, and within the dry forests (i.e. those growing on *Pseudotsuga menziesii* (Mirb.) Franco potential vegetation types) of southern Idaho.

4.1. Free selection in the moist forests

Management objective. Maintain a forest that provides a sense of place (see footnote 1) for forest visitors and maintain a native forest feeling while reducing wildfire risk to historical buildings (wildland–urban interface). Also encourage the regeneration and development of early seral species but keep a component of old trees that serve as old-growth surrogates.

Theme. Maintain a functioning forest composed of a suite of vegetative structural stages and compositions from stand initiation through old forest interspersed in patches at a fine scale while reducing intermediate canopy layers that can facilitate a surface fire transitioning into tree crowns. Create forest characteristics (e.g., big trees, standing dead trees, lush and diverse ground level vegetation of forbs and mosses) that will invoke a feeling of serenity and instill quietness. Provide habitat elements (e.g., down wood, cover, snags) that favor small mammals and birds.

4.1.1. Desired forest conditions

Fire, weather, insects, and diseases historically played major roles in regenerating and maintaining the moist forests of the northern Rocky Mountains (Hann et al., 1997). These disturbances gave rise to a diversity of forest structures, compositions and ages within groups and patches of many different sizes and arranged in a variety of mosaics. The composition and structure ranged from an early seral single storied condition (e.g., *P. monticola*, *Pinus ponderosa* Dougl. ex Laws., *Pinus contorta* Dougl. Ex Loud.) to multi-storied, multi-species structures (e.g., *P. monticola*, *P. ponderosa*, *P. contorta*, *Abies grandis* (Dougl. ex D. Don) Lindl., *T. heterophylla*, *T. plicata*) with a high diversity of tree diameters, heights, crown classes, and decadence (Marshall, 1928).

Using this historical evidence as a reference, we defined a functioning forest as one containing a mix of tree species arranged in single-cohort groups and clumps of various sizes and ages emulating conditions that might have been created by a series of fine-scale disturbances. In addition to containing ground-level, mid-story, and overstory trees, a functioning moist forest would include snags, down logs, shrubs, forbs, and an organic rich forest floor with coarse woody debris scattered throughout in various stages of decay. This mosaic also includes structure in which the crown base height and surface fuel conditions are such that the risk of crown ignition is minimized if a fire occurred. We recognize the variation that occurs within a stand and what defines a functioning system is variable from point to point within a stand. We also recognize that trees (single and multiple species) often regenerate and develop in groups and clumps often in response to the creation of small canopy gaps. Also, a functioning moist forest would contain endemic levels of native insects and diseases.

4.1.2. Untreated stand conditions (current stand conditions)

The mixed (*P. contorta*, *P. ponderosa*, *P. monticola*, *L. occidentalis*, *T. plicata*, *T. heterophylla*, *Picea engelmannii* Parry ex Engel., *A. grandis*, *P. menziesii*, *Populus* spp.) moist forest surrounding the historical buildings (built by the Civilian Conservation Corp in the 1930s) at the Priest River Experimental Forest located in northern Idaho had dominant trees approximately 120 years old (Fig. 1). The trees were arranged in a mosaic of tree groups (10–30 groups/ha) and isolated trees (Fig. 2). Tree density within the groups was highly variable ranging from 124 to 1920 trees/ha while the mean stand density of live trees was 298 trees/ha occurring both in groups and isolated trees (Fig. 2). The site contains many root and stem diseases and, in particular, *Cronartium ribicola* Fisch. (an exotic stem disease, blister rust) in the *P. monticola* and *Arceuthobium campyolpodum* f *laricis* (mistletoe) that infects the crowns of *L. occidentalis*.

4.1.3. Free selection implementation

In applying the system, we continuously integrated autecological factors such as wind firmness, disease resistance, tree crown architecture and its relations to tree development, tree tolerance, tree longevity, a tree's response to wounding, regeneration requirements (e.g., opening size, seed bed conditions), fire tolerance, potential root grafting, and groups of trees functioning as a unit (cohort). Not only do these factors need consideration for the current treatment, but they need inclusion within the context of future forest dynamics and forest treatments that are implicit in selection systems. During implementation, these elements were continually being evaluated within the context of structures and compositions that were presented in the stand and, most importantly, what structures and compositions were to remain after treatment and subsequent vegetation response. For example, we recognized that mortality would continue in the stands since high amounts of tree disease occurred on the site. Because these stands contained groups and clumps of trees with a wide range of sizes, ages, decadence, and species combinations, an entire group was removed or left rather than disturbing or removing a portion of a group.

Because *P. monticola* and *L. occidentalis* were desired species to regenerate now and in the future, areas around individual trees and groups of *P. monticola* and *L. occidentalis* were often cleared of vegetation to create conditions where these species could regenerate (Haig et al., 1941). Even though *P. monticola* contains some natural resistance to *C. ribicola* (Hoff et al., 1976), some *C. ribicola* resistant pines were planted to supplement this resistance. Because *A. laricis* (mistletoe) infects the crowns of *L. occidentalis,* future treatments (e.g., girdling, cutting, harvesting) will need to be planned after a cohort of *L. occidentalis* seedlings become established to allow them to develop. Coarse woody debris (CWD) will be continually created after the treatments, allowing us latitude in leaving CWD for soil productivity and

Fig. 1. A photograph showing an untreated moist forest surrounding historical buildings located at the Priest River Experimental Forest in northern Idaho. Note the large amount of down and dead material with minimal ground-level vegetation. The dominant trees in the stand are approximately 120 years old.

wildlife habitat (Graham et al., 1994; Reynolds et al., 1992). In addition, there was evidence that canopy gaps created by the treatments will be rapidly occupied by new seedlings indicating that within 5–10 years another treatment will be required to tend both the overstory and regeneration cohorts and, if necessary, decrease their amount to affect their role as ladder and surface fuels.

4.1.4. Stand conditions after treatments

The first treatment removed a large portion of the standing dead trees that could be used for lumber. Four years later, trees were removed that were a hazard to the buildings. Three years after that, the stands around the buildings were treated using free selection and the surface fuels were reduced using a combination of prescribed burning, mechanical chunking (creating chunks of stems $\approx$ 100–1000 cm^3), and piling and burning (Fig. 3). These surface fuel treatments were applied to balance CWD's role as a fuel while

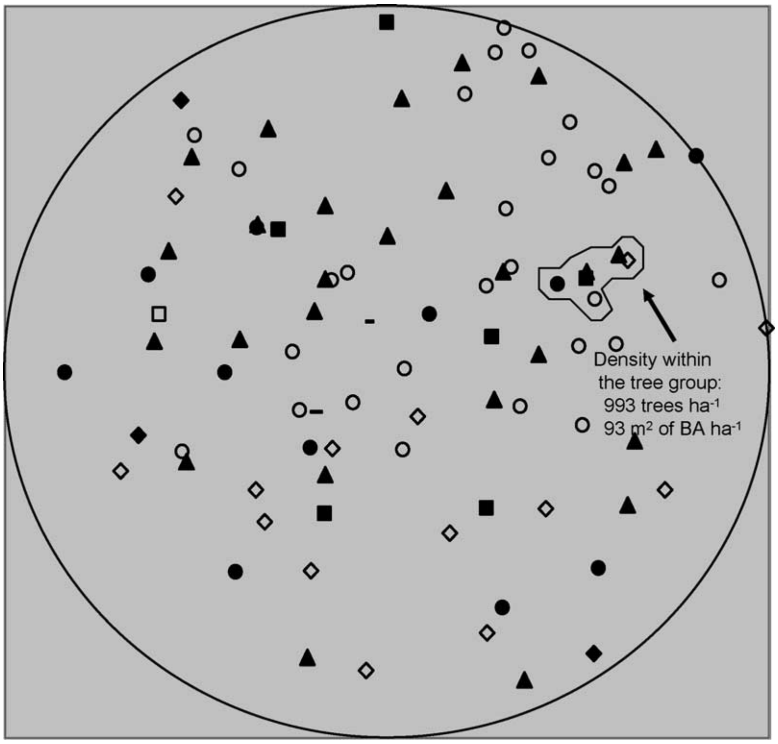

Fig. 2. An illustration showing the spatial distribution of an untreated moist forest surrounding historical buildings located at the Priest River Experimental Forest in northern Idaho. The area represented by the circle is approximately 0.2 ha and ◆ = live *P. monticola*, ● = live *L. occidentalis*, ▲ = live *T. plicata*, ■ = live *P. menziesii*, ◇ = dead *P. monticola*, ○ = dead *L. occidentalis*, □ = dead *P. menziesii*, - = live *A. grandis*, and — = live *P. ponderosa*.

considering its value for wildlife habitat and maintaining soil productivity. This is an example of how a comprehensive view of forests, incorporated in a vision, is more than tree composition and structure.

We have had minimal negative reactions to the results from stakeholders that use the Experimental Forest, and positive reviews from professional societies (Society of American Foresters, Ecological society of America), and universities. After three entries over a 10-year period, we reduced the surface fuels and reduced canopy continuity, thus decreasing fire hazard while maintaining a functioning forest containing *P. contorta* (3%), *P. ponderosa* (<1%), *P. monticola* (12%), *L. occidentalis* (24%), *T. plicata* (44%), *T. heterophylla* (7%), *P. engelmannii* (<1%), *A. grandis* (4%), *P. menziesii* (5%), and *Populus* spp. (<1%) (Fig. 3).

The resulting 120-year-old high canopy structure is arranged in an irregular fashion (Figs. 3 and 4). Because of their clumpy nature, the stands have up to 40 tree groups/ha, ranging in size from 0.0009 to 0.046 ha (Fig. 4). The clumps with high forest canopy contained a mixture of tree species, tree sizes, snags, and decadence. Tree density within some of the groups exceeded 1600 trees/ha yet the overall mean stand density (both live and dead trees) was less than 300 trees/ha (Fig. 4). Openings were created around *P. monticola* and *L. occidentalis* providing opportunities for regeneration and these openings decreased the canopy bulk density in the stands thereby reducing crown fire hazard (Scott and Reinhardt, 2001) (Fig. 4). After the fuel treatments, the forest floor was covered with 9.5–73.9 Mg/ha (mean = 36.3 Mg/ha) of coarse woody debris and a rich organic layer 3–7 cm in depth (Fig. 3). Graham et al. (1994) recommended 37–74 Mg/ha of coarse woody debris to maintain soil productivity in these settings. Abundant (tens of thousands of trees per hectare) regeneration ranging from *P. monticola* to *T. plicata* has developed in a relatively irregular fashion along with a rich understory of forbs, shrubs, and grasses. Mossy areas in wet seeps are also developing. How these new cohorts develop will determine the kind (cleaning, canopy removal) and timing of future tending operations to insure that all representative species develop and the clumpy irregular forest structure is maintained which is the essence of all selection systems. Moreover, in the future these vegetative layers will need to be treated in concert with the other canopy layers to insure they do not facilitate the ignition and maintenance of crown fires (Scott and Reinhardt, 2001; Jain et al., 2004).

Fig. 3. A photograph showing a treated moist forest surrounding historical buildings located at the Priest River Experimental Forest in northern Idaho. Surface fuels were mechanically treated creating chunks that decreased the hazard fuels and enhanced decomposition.

4.2. Free selection in the dry forests

Management objective. restore and maintain the old-growth character of *P. ponderosa* stands in the dry forests of southern Idaho. In particular, decrease the risk of lethal stand replacing fires in the Boise Basin Experimental Forest located near Idaho City, ID.

Theme. Maintain a functioning forest that includes large and mature *P. ponderosa* that has a park-like, old-growth appearance. This includes decreasing the risk from crown fire. Develop stand structures in which frequent low intensity surface fires can be used to maintain the desired conditions without putting the large mature *P. ponderosa* at risk.

4.2.1. Desired forest conditions

For the restoration of these dry forests, we used a reference condition defined by reports of forest settings prior to European settlement (late 1800s) (Fulé et al., 1997). Most working hypotheses suggest that dry forests were dominated by *P. ponderosa* but species composition has changed since the late 1800s as a result of (singly or in combination) climate change and/or oscillations, fire exclusion, timber harvesting, and animal grazing (Covington et al., 1994; Hann et al., 1997; Everett et al., 1994). Low intensity, non-lethal

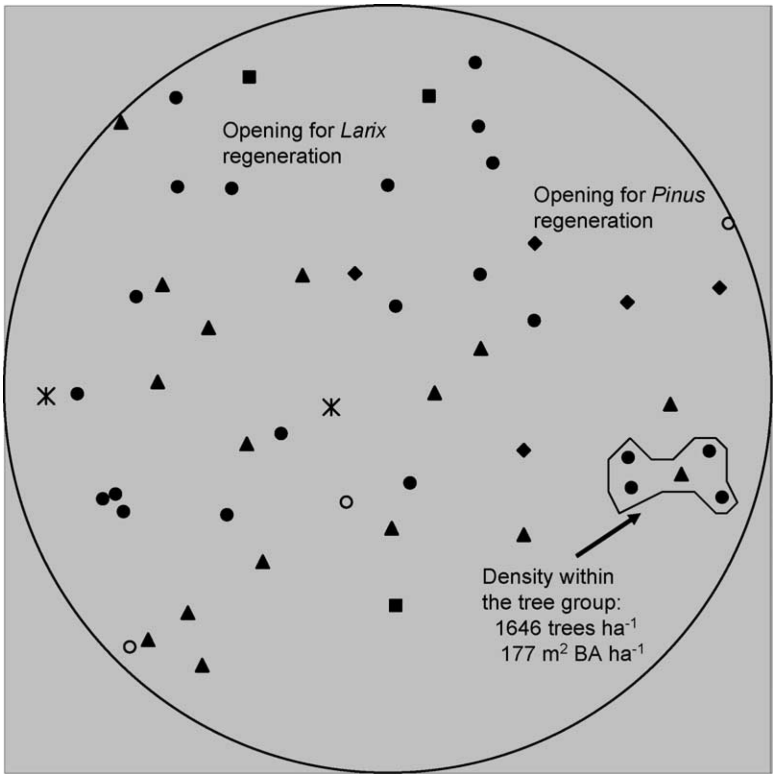

Fig. 4. An illustration showing the spatial distribution of a treated moist forest surrounding historical buildings located at the Priest River Experimental Forest in northern Idaho. The area represented by the circle is approximately 0.2 ha and ◆ = live *P. monticola*, ● = live *L. occidentalis*, ▲ = live *T. plicata*, ■ = live *P. menziesii*, ◇ = live *T. heterophylla*, and ○ = dead *L. occidentalis*.

surface fires were frequent in the dry forests dominated by *P. ponderosa* with a fire return interval most often less than 20 years (Steele et al., 1986; Agee, 1993; Fulé et al., 1997; Hann et al., 1997; Sloan, 1998). In addition, endemic populations of insects and diseases interacted with these fires to create a mosaic of forest conditions (Kaufmann et al., 2000). In general, minimal amounts of shrubs and trees (ladder fuels) occupied the lower vegetative layers (Pearson, 1950; White, 1985; Harrod et al., 1999). Snags, decadence, grasses and forbs, and down logs were irregularly distributed across landscapes (Hann et al., 1997). Because of frequent fires that occurred at that time, surface organic materials did not usually accumulate and ectomycorrhizae and fine roots tended to develop deep in the mineral soil thereby protecting them from damage during the frequent surface fires (Harvey et al., 1999).

Using this information as a reference, we defined the immediate and future desired conditions for the *P. ponderosa* stands in southern Idaho as consisting of an aggregation of the forested clumps of structural stages ranging from stand initiation to old forest like those that existed prior to 1900. Grasses and other ground level vegetation are an integral component of the desired setting reflecting the open, park-like appearance. Organic layers fluctuate in depth reminiscent to those maintained by low intensity surface fires. Crown base heights will be high (>10 m), and because of the tree patches and low tree density, canopy bulk density will be low. Ladder fuels will vary depending on structural stage, but canopy discontinuity will minimize crown fire risk.

4.2.2. Untreated stand conditions (current stand conditions)

Large *P. ponderosa* tended to dominate the ridge tops and side slopes of stands within the Experimental Forest in which no harvesting has occurred.

Fig. 5. A photograph of an untreated dry forest located on the Boise Basin Experimental Forest in southern Idaho. Note the inherent clumpy nature of the stems and the low crown base heights and the presence of ladder fuels.

Because fire has been excluded in the Forest for over 100 years, an admixture of *P. menziesii* and *P. ponderosa* occupied the intermediate and mid-canopy layers (Fig. 5). These small trees act as ladder fuels that allow wildfires or prescribed fires to burn crowns of the large *P. ponderosa*. The dominant trees, 150–450 years old, occurred as isolated trees and in groups of trees with interlocking crowns (5–20 groups/ha) (Fig. 6). The size of these tree groups ranged from 0.003 to 0.040 ha and tree density within the groups ranged from 54 to 1976 trees/ha. The mean stand density of live trees averaged 180 trees/ha and the diameters of the dominant trees ranged from 20 to 86 cm.

At the base of the large *P. ponderosa*, needle and bark slough had accumulated resulting in deep layers (over 8.9 cm) of organic material. These layers contained over 0.005 g/cm^3 of fine roots (obtained from soil cores, 7.5 cm $\times$ 30 cm, extracted from

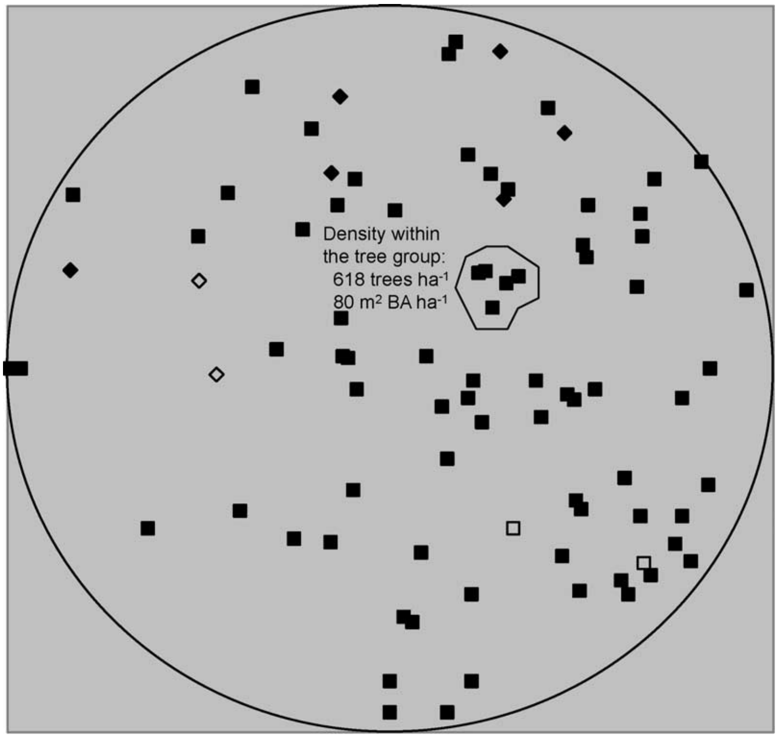

Fig. 6. An illustration showing the spatial distribution of an untreated dry forest located on the Boise Basin Experimental Forest in southern Idaho. The area represented by the circle is approximately 0.4 ha and ■ = live *P. ponderosa*, □ = dead *P. ponderosa*, ◆ = live *P. menziesii*, and ◇ = dead *P. menziesii*.

around the base of large *P. ponderosa*). Because of the presence of fine roots in these layers, the destruction of these layers could stress or even kill these large trees. This observation exemplifies the importance of incorporating the full range of forest components (e.g., soil, trees, snags, shrubs) when developing a vision and free selection prescriptions.

4.2.3. Free selection implementation

Free selection in the dry forests is similar to that for the moist forests. We decreased the ladder fuels and removed as much *P. menziesii* as possible while still maintaining the integrity of the stands. We wanted to maintain the clumpy nature of the large *P. ponderosa*, plus increase regeneration of *P. ponderosa*, grasses, forbs, and shrubs. When marking, we were aware of stand densities (>28 m^2 basal area/ha) at which *Dendroctonus* spp. (bark beetles) become problematic (Schmid and Mata, 1992) and watched for locations where *Armillaria* spp. (root disease) would likely threaten or kill *P. menziesii*. However, we expect some future disease and insect mortality, as in the past, and mortality from weather and fire. The stands have gentle, sloping (<35% slope) and undulating topography, requiring shifts in tree density and species composition from one place to another. Along ridges we kept large *P. ponderosa* but often emphasized shrub communities on more northerly exposures and at the base of slopes. On the steeper (>30%), southerly slopes, we created or maintained conditions encouraging the development of grass and forb communities. By maintaining this pattern of species occurrence and stand structure, we maintained the natural heterogeneity of the site.

4.2.4. Stand conditions after treatments

The cutting and cleaning operations reduced the canopy bulk density and continuity along with reducing the ground level and mid-story *P. menziesii* trees (ladder fuels) (Fig. 7). After treatment, 91% of the trees in the stands were *P. ponderosa* and 9% *P. menziesii*. The remaining 150–450-year-old high canopy was irregularly distributed (Figs. 7 and 8) with up to 17 tree groups/ha ranging in size from 0.0009 to 0.022 ha (Fig. 8). Tree density within some of these groups exceeded 1000 trees/ha, but the overall mean stand density (both live and dead trees) was less than 100 trees/ha (Figs. 7 and 8). Basal area within

Fig. 7. A photograph of a treated dry forest located on the Boise Basin Experimental Forest in southern Idaho. Note the presence of large yellow *P. ponderosa* and the distance between their crown bases and the surface fuels. The surface fuels will be burned after the uncharacteristically deep organic layers around the base of the trees are reduced.

some tree groups exceeded 200 m^2/ha but the stand basal area averaged 16.1 m^2/ha (Fig. 8). This density is below the threshold where *Dendroctonus* spp. beetles frequently stress or kill trees (Schmid and Mata, 1992).

Mechanical methods and/or prescribed fire are being used to reduce the organic layers around large *P. ponderosa*, but in a way that prevents fine root mortality and encourages their development in the deeper mineral soil layers (Fig. 9). This includes mixing the organic layers and burning the surface organic material when the moisture content of the lower organic layers exceeds 100% and the temperature at that depth is below 5 °C (fine root activity is minimal at this temperature). Mixing the surface organic layers allows moisture to more readily penetrate and, because canopy cover was reduced,

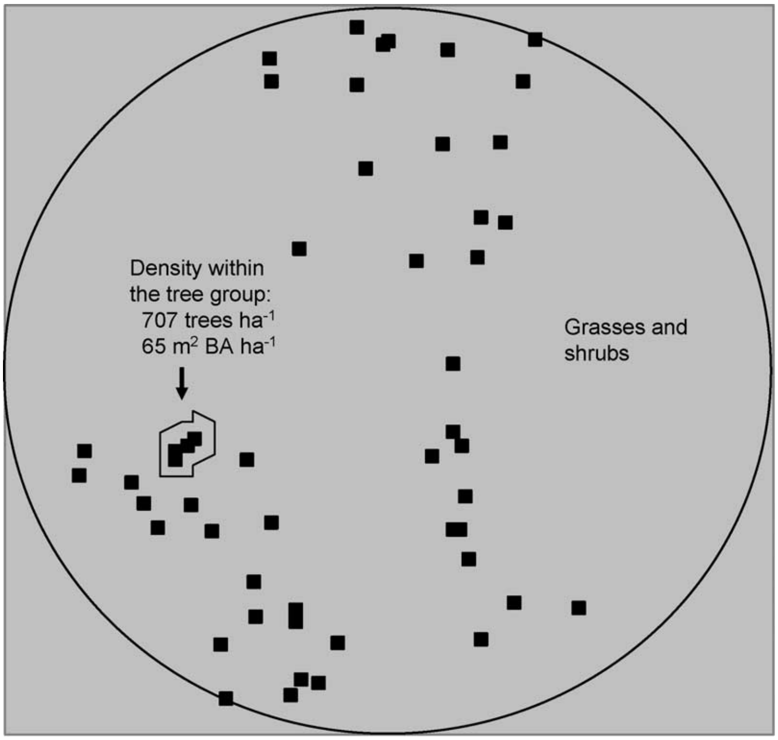

Fig. 8. An illustration showing the spatial distribution of a treated dry forest located on the Boise Basin Experimental Forest in southern Idaho. The area represented by the circle is approximately 0.4 ha and ■ = live *P. ponderosa*.

more heat reaches these layers fostering decomposition. Burning under these conditions allows the surface layers (2–4 cm in depth) to be consumed, similar to peeling an onion. These conservative techniques reduce the deep organic layers and encourage fine root development in the mineral soil (Fig. 9). When we find the fine roots are concentrated in the mineral soil, we will use a low intensity surface fire to clean the forest floor and help maintain the desired conditions. This is an example of how the intensity and timing of treatments used in free selection are predicated on how forest components (i.e. surface organic layers and fine roots) respond to treatments.

5. Discussion

"Free selection" is grounded in forest ecology and draws upon proven silvicultural practices while building on past knowledge. As early as 1524, group selection systems were used in Europe to enhance natural regeneration and protect seed trees from damaging winds (Fernow, 1907). Similarly, Marquis (1965) used patch cutting to favor the regeneration of shade-intolerant species. Building on this information, the concept of patch-selection system was introduced by Leak and Filip (1977). This hybrid selection system combined the cutting of fixed-area patches with single-tree selection system designed to regenerate both shade-intolerant and shade-tolerant species.

By no means do we suggest that traditional even-aged and uneven-aged silvicultural systems cannot be developed and presented quantitatively in prescriptions to address many emerging forest management issues. What we are suggesting is an alternative to traditional even-aged and uneven-aged systems for those situations in which quantification of management objectives is difficult to impossible, or the quantification and/or decision making rule sets required are so complex that they become unwieldy and/or impossible to implement. In addition, by using

Fig. 9. (A) This photograph shows the top layers of organic material accumulated at the base of mature *P. ponderosa* being burned. By burning when the lower layers are moist (moisture content > 100%) only the top layers will be removed. Burning is preferred when the layers are cool (<5 °C) and fine root activity is minimal. (B) Mixing the organic layers allows moisture and heat to penetrate thus encouraging decomposition. Both of these treatments are designed to decrease the depth of the organic layers at the base of the mature trees and encourage fine root development in mineral soil. It may take several of these treatments to reduce the organic layers to a level at which fine root activity occurs primarily in the mineral soil. Under these conditions fire can burn at the base of these trees without damaging the fine roots. Note the presence of snow when the treatments were applied.

a comprehensive description of the short- and long-term desired conditions of a forest presented in a vision, it may be more readily communicated to disciplines outside of forestry (e.g., law, social, recreation, wildlife) and to the public at large. These disciplines and the public may respond more favorable to a comprehensive and well thought out forest description than a list of technical forest descriptors such as crown competition factor, species preference rules, stand density index, torching index, or canopy bulk density.

Rarely have silvicultural systems and/or methods been developed solely to maintain the integrity and function of forests as ecological systems. They have not commonly been recognized as a means for addressing objectives like sustaining the sense of place in forests (see footnote 1), emulating natural stand development, or for maintaining ectomycorrhizae habitat (important for the habitat of goshawk prey). Free selection, and using a vision to guide it, is well suited to these objectives and others that are not readily quantifiable (see Franklin et al. (2002), footnote 2). Forest products would also be produced, albeit in uncertain quantities and at indeterminate intervals. In the wildland–urban interface of northern Idaho, approximately 50 m^3/ha of commercial product was removed during the treatments described here. In southern Idaho, the *P. ponderosa* restoration project yielded approximately 35 m^3/ha of commercial products and an undetermined amount of domestic firewood.

As we implemented the free selection system in these cases, we found it challenging and exciting. Rather than choosing trees to remove in the treatments, we concentrated on the forest components (e.g., soil, trees, shrubs, disease) being left, and projected how they would respond in both the short- and long-term. Moreover, the process of implementing the treatments necessitated continued discussion among the people doing the marking. That helped to channel their collective silvicultural knowledge into an integrated vision when making on-the-ground decisions. The vision of naturally occurring clumps and groups of vegetation in the stands served as a reference point for decisions on where to remove trees and in what numbers (Figs. 2, 4, 6 and 8). A shared concept of the functioning forest guided the treatments even while we made the stands more resilient and resistant to crown fire. We did this by decreasing the overall stand density, decreasing surface fuels, and raising crown base heights. In both forest settings we created openings for regeneration (e.g., tree, shrub, grass), thereby meeting a perquisite for long-term success of the selection system (Figs. 3, 4, 7 and 8). However, we recognize that in both the moist and dry forests that subsequent treatments (e.g., canopy removal, prescribed fire, cleanings, thinning, site preparation, planting) must occur to further promote the development of the desired forest structures and compositions as disclosed in the vision. These follow-up treatments are critical to the success of any selection system, and many will provide commercial products.

Using a vision to plan and implement forest treatments may appear extremely complex. However, we found that experienced foresters, technicians, and contractors all have the ability to understand and apply stand treatments effectively when a vision is thoroughly articulated and effectively communicated. Our success in using a vision for implementing free selection was similar to the way people respond to and implement a good prescription for traditional selection systems.

The demands on forests by society are ever changing, as are the forest management objectives that guide our stewardship of the forests in our care. This is exemplified by the passing of the Healthy Forest Restoration Act of 2003 in the United States. It includes provisions to reduce hazardous fuels and restore healthy forest conditions on lands of all ownerships (USDA, 2004). However, it will take tens to hundreds of years before management will create forest conditions that fulfill these goals. The free selection system we propose, and the kind of vision statements that we suggest for guiding its implementation, will serve as additional tools for future forest management. Its successful application requires a strong appreciation of the art and science of silviculture. Smith (1972) predicted "Silviculture fitted to demonstratable realities of nature and human need will call forth the evolution of methods or treatments more varied than our wildest present imagination can encompass". Our concept of free selection may help to bring that prophecy to reality.

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